# MEAN SOUNDINGS FOR THE GULF OF MEXICO AREA

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ABSTRACT

Mean aerological data for the Gulf of Mexico area have been prepared from 10-year records for three stations. Mean monthly height, temperature, and relative humidity data are tabulated for constant pressure surfaces. More detailed information, including density, potential temperature, and specific humidity, is shown for the mean "hurricane season" sounding. The mean data are compared with those previously presented for the West Indies area and some of the interesting climatological features are discussed.

## 1. INTRODUCTION

Recently, mean sounding data have been presented for the West Indies area based on 10-year records for Miami, Fla., San Juan, P.R., and Swan Island [1]. At about the same time, mean aerological data were being prepared for individual U.S. Weather Bureau and cooperative stations for the same 10-year period, 1946–55 [2]. Since the availability of these mean data for the individual stations greatly simplifies the preparation of mean soundings for geographical areas, it was decided to prepare, for comparative purposes, mean soundings for the Gulf of Mexico area by combining the published means for Brownsville, Tex., Burrwood-New Orleans,[2] La., and Havana, Cuba. This new set of data for a slightly different geographical area (fig. 1) should be useful as a check on the representativeness of the mean West Indies data [1], and also provide information on seasonal variations of temperature, pressure, and humidity over the northern Gulf of Mexico.

## 2. PROCESSING OF DATA

In preparing the mean sounding data for the Gulf of Mexico area, the information was processed in a somewhat different manner than that employed in computing the mean West Indies sounding. Detailed information on the length of record and the techniques employed in reducing bias in the monthly means at the upper levels at the individual stations is given in [2]. In contrast to the mean West Indies soundings, the pressure-height data for the Gulf soundings were not computed from the mean temperature and humidity data; the height data for the standard pressure surfaces were obtained by simply averaging the reported heights at the individual levels. Checks made in [1] suggest that only very minor inconsistencies are introduced by treating the data in this way. To the extent possible, mean data are shown for all standard levels up to 30 mb. as in [1], although relatively few observations reached this level in the earlier years. The mean surface pressures were reduced to mean sea level pressures simply by considering the mean elevation of the three stations and the mean temperature in the layer near the surface.

The mean values are based entirely on the 0300 GMT observations in both sets of data so that radiation errors, noted in radiosonde records in the past [3], need not be considered. The observations were scheduled at local times varying from approximately 10:30 p.m. at San Juan to about 8:30 p.m. at Brownsville. Since relatively small mean diurnal differences can be expected over a 2-hour period [3] and since any effect of this type introduced by the San Juan and Brownsville data would tend to be reduced by the data from the other stations, which are all within 10° longitude of each other, it is felt that diurnal differences can safely be neglected in comparing the Gulf and West Indies soundings.

## 3. THE MEAN AEROLOGICAL DATA

The monthly and annual temperature, height, and relative humidity data for the standard pressure surfaces for the Gulf of Mexico area, obtained by averaging the

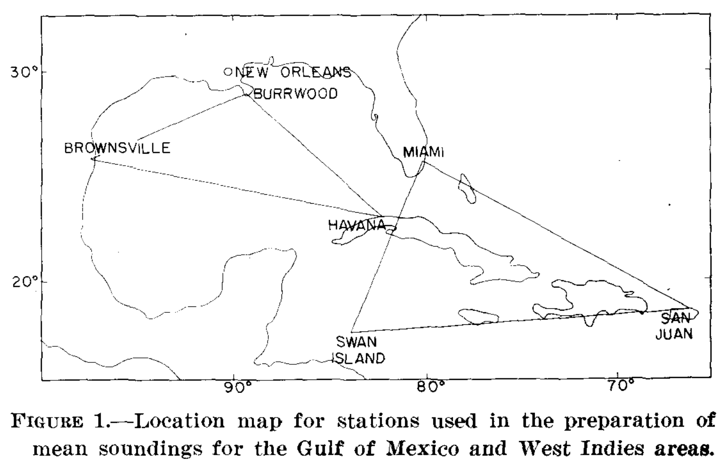


FIGURE 1.—Location map for stations used in the preparation of mean soundings for the Gulf of Mexico and West Indies areas.

[1] This report was prepared with the support of the U.S. Weather Bureau and was preprinted as National Hurricane Research Project Report No. 30, April 1959.

[2] Data taken at New Orleans for the period Jan. 1947–July 1950 and at Burrwood for Jan.–Dec. 1946 and Aug. 1950–Dec. 1955 were combined in preparing the mean data [2]. This combined record will be referred to as Burrwood in the subsequent discussion.

TABLE 1.—*Mean temperature (° C.) at standard pressure surfaces for Gulf of Mexico area. All values above the dashed line are negative*

| Pressure (mb.) | January | February | March | April | May | June | July | August | September | October | November | December | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 56.0 | 57.3 | 56.5 | | 53.1 | | 51.5 | 52.7 | 52.5 | 54.0 | 54.3 | 55.6 | 54.3 |
| 40 | 60.6 | 60.7 | 60.3 | 57.2 | 55.7 | 58.7 | 55.7 | 56.2 | 56.5 | 57.3 | 58.5 | 59.6 | 58.1 |
| 50 | 65.5 | 64.4 | 65.2 | 62.1 | 59.3 | 59.1 | 58.8 | 59.0 | 59.3 | 60.4 | 61.9 | 63.5 | 61.5 |
| 60 | 69.5 | 68.9 | 69.7 | 66.5 | 63.4 | 62.6 | 61.9 | 61.9 | 62.5 | 63.4 | 65.5 | 67.1 | 65.2 |
| 80 | 74.0 | 73.0 | 73.3 | 73.0 | 70.2 | 69.1 | 67.1 | 67.5 | 68.3 | 69.9 | 71.7 | 72.2 | 70.8 |
| 100 | 72.9 | 71.8 | 72.0 | 69.9 | 71.1 | 72.7 | 70.2 | 71.0 | 73.1 | 73.8 | 72.8 | 71.7 | 71.9 |
| 125 | 68.0 | 67.3 | 67.3 | 66.4 | 68.4 | 71.1 | 70.3 | 70.5 | 72.0 | 71.2 | 71.1 | 69.7 | 69.4 |
| 150 | 63.4 | 62.7 | 63.3 | 63.5 | 65.3 | 66.5 | 66.7 | 66.2 | 66.6 | 66.3 | 66.2 | 64.9 | 65.1 |
| 175 | 59.9 | 58.9 | 59.7 | 60.7 | 60.9 | 60.9 | 61.2 | 60.4 | 60.4 | 60.4 | 61.4 | 61.4 | 60.5 |
| 200 | 56.3 | 55.8 | 56.3 | 56.9 | 56.0 | 54.9 | 55.1 | 54.2 | 53.9 | 54.7 | 56.1 | 57.0 | 55.6 |
| 250 | 47.6 | 48.2 | 47.8 | 47.3 | 45.6 | 43.4 | 43.2 | 42.6 | 42.2 | 43.9 | 45.7 | 47.2 | 45.4 |
| 300 | 38.5 | 39.2 | 38.4 | 37.8 | 36.1 | 33.6 | 33.2 | 32.6 | 32.7 | 34.4 | 36.4 | 37.8 | 35.9 |
| 350 | 30.3 | 30.9 | 29.9 | 29.5 | 27.8 | 25.2 | 24.8 | 24.3 | 24.1 | 26.3 | 28.2 | 29.6 | 27.6 |
| 400 | 23.0 | 23.6 | 22.5 | 22.3 | 20.6 | 18.1 | 17.7 | 17.3 | 17.2 | 19.2 | 21.0 | 22.3 | 20.4 |
| 450 | 16.5 | 17.3 | 16.1 | 15.9 | 14.3 | 12.0 | 11.8 | 11.4 | 11.3 | 13.0 | 14.8 | 16.0 | 14.2 |
| 500 | 10.8 | 11.7 | 10.4 | 10.3 | 8.8 | 6.9 | 6.8 | 6.4 | 6.3 | 7.7 | 9.4 | 10.5 | 8.8 |
| 550 | 5.9 | 6.8 | 5.4 | 5.3 | 4.0 | 2.3 | 2.4 | 2.0 | 1.9 | 3.1 | 4.6 | 5.7 | 4.1 |
| 600 | 1.6 | 2.5 | 1.0 | .8 | .4 | 1.7 | 1.5 | 2.1 | 2.0 | .9 | .4 | 1.4 | .1 |
| 650 | 2.2 | 1.5 | 3.2 | 3.4 | 4.6 | 5.6 | 5.4 | 5.8 | 5.7 | 4.6 | 3.3 | 2.4 | 4.0 |
| 700 | 5.6 | 5.1 | 6.8 | 7.0 | 8.3 | 9.1 | 9.0 | 9.4 | 9.1 | 8.0 | 6.7 | 5.6 | 7.5 |
| 750 | 8.3 | 7.9 | 9.7 | 10.1 | 11.6 | 12.4 | 12.4 | 12.7 | 12.2 | 10.9 | 9.4 | 8.4 | 10.5 |
| 800 | 10.4 | 10.0 | 11.8 | 12.7 | 14.4 | 15.4 | 15.6 | 15.8 | 15.1 | 13.3 | 11.6 | 10.6 | 13.1 |
| 850 | 11.9 | 11.6 | 13.8 | 15.0 | 17.1 | 18.3 | 18.6 | 18.5 | 17.9 | 15.7 | 13.4 | 12.2 | 15.3 |
| 900 | 13.6 | 13.5 | 15.5 | 17.2 | 19.7 | 20.9 | 21.4 | 21.7 | 20.7 | 18.3 | 15.3 | 14.0 | 17.8 |
| 950 | 15.3 | 15.5 | 17.3 | 19.2 | 20.6 | 23.3 | 23.8 | 24.2 | 23.4 | 21.0 | 17.6 | 16.0 | 19.8 |
| 1,000 | 17.1 | 17.5 | 19.3 | 21.4 | 24.0 | 25.8 | 26.2 | 26.6 | 25.8 | 23.5 | 19.9 | 17.9 | 22.1 |
| Sfc | 16.7 | 17.2 | 19.1 | 21.6 | 24.1 | 26.0 | 26.5 | 26.8 | 25.8 | 23.1 | 19.4 | 17.3 | 22.0 |

TABLE 2.—*Mean heights of standard pressure surfaces (meters) for Gulf of Mexico area. Sea level pressure (SLP) is given in millibars*

| Pressure (mb.) | January | February | March | April | May | June | July | August | September | October | November | December | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 23,753 | 23,738 | 23,739 | | 23,903 | | 24,106 | 24,085 | 24,071 | 23,927 | 23,814 | 23,773 | 23,891 |
| 40 | 21,936 | 21,905 | 21,928 | 22,000 | 22,074 | 22,179 | 22,250 | 22,264 | 22,219 | 22,106 | 21,983 | 21,957 | 22,067 |
| 50 | 20,527 | 20,515 | 20,554 | 20,610 | 20,668 | 20,771 | 20,843 | 20,860 | 20,818 | 20,706 | 20,592 | 20,553 | 20,668 |
| 60 | 19,427 | 19,419 | 19,453 | 19,497 | 19,555 | 19,642 | 19,707 | 19,723 | 19,678 | 19,577 | 19,477 | 19,440 | 19,550 |
| 80 | 17,744 | 17,730 | 17,760 | 17,787 | 17,829 | 17,903 | 17,954 | 17,966 | 17,929 | 17,839 | 17,761 | 17,728 | 17,828 |
| 100 | 16,448 | 16,426 | 16,450 | 16,471 | 16,509 | 16,583 | 16,618 | 16,636 | 16,609 | 16,538 | 16,457 | 16,441 | 16,516 |
| 125 | 15,116 | 15,096 | 15,127 | 15,136 | 15,187 | 15,272 | 15,295 | 15,314 | 15,305 | 15,225 | 15,145 | 15,115 | 15,194 |
| 150 | 14,005 | 13,982 | 14,017 | 14,023 | 14,081 | 14,186 | 14,201 | 14,220 | 14,211 | 14,140 | 14,055 | 14,007 | 14,094 |
| 175 | 13,050 | 13,020 | 13,058 | 13,072 | 13,137 | 13,270 | 13,256 | 13,273 | 13,264 | 13,193 | 13,111 | 13,061 | 13,147 |
| 200 | 12,211 | 12,177 | 12,214 | 12,236 | 12,297 | 12,395 | 12,417 | 12,430 | 12,422 | 12,351 | 12,272 | 12,224 | 12,304 |
| 250 | 10,768 | 10,734 | 10,770 | 10,792 | 10,845 | 10,932 | 10,953 | 10,962 | 10,950 | 10,887 | 10,821 | 10,779 | 10,849 |
| 300 | 9,540 | 9,511 | 9,542 | 9,560 | 9,605 | 9,679 | 9,698 | 9,704 | 9,690 | 9,638 | 9,582 | 9,548 | 9,608 |
| 350 | 8,463 | 8,436 | 8,463 | 8,479 | 8,517 | 8,578 | 8,595 | 8,600 | 8,585 | 8,543 | 8,496 | 8,468 | 8,519 |
| 400 | 7,500 | 7,475 | 7,498 | 7,512 | 7,544 | 7,595 | 7,603 | 7,614 | 7,598 | 7,563 | 7,524 | 7,502 | 7,544 |
| 450 | 6,631 | 6,609 | 6,628 | 6,642 | 6,668 | 6,711 | 6,727 | 6,728 | 6,713 | 6,684 | 6,650 | 6,632 | 6,669 |
| 500 | 5,822 | 5,803 | 5,818 | 5,831 | 5,852 | 5,888 | 5,903 | 5,903 | 5,886 | 5,863 | 5,835 | 5,821 | 5,852 |
| 550 | 5,084 | 5,068 | 5,078 | 5,090 | 5,108 | 5,140 | 5,155 | 5,155 | 5,137 | 5,116 | 5,093 | 5,082 | 5,109 |
| 600 | 4,396 | 4,381 | 4,389 | 4,400 | 4,414 | 4,441 | 4,456 | 4,453 | 4,437 | 4,420 | 4,401 | 4,393 | 4,415 |
| 650 | 3,757 | 3,745 | 3,748 | 3,759 | 3,771 | 3,795 | 3,809 | 3,806 | 3,791 | 3,777 | 3,761 | 3,755 | 3,773 |
| 700 | 3,151 | 3,141 | 3,140 | 3,150 | 3,159 | 3,180 | 3,196 | 3,191 | 3,175 | 3,163 | 3,151 | 3,148 | 3,162 |
| 750 | 2,589 | 2,581 | 2,576 | 2,585 | 2,591 | 2,609 | 2,623 | 2,617 | 2,604 | 2,597 | 2,587 | 2,587 | 2,596 |
| 800 | 2,048 | 2,040 | 2,032 | 2,040 | 2,042 | 2,060 | 2,075 | 2,069 | 2,055 | 2,049 | 2,043 | 2,045 | 2,050 |
| 850 | 1,541 | 1,534 | 1,523 | 1,529 | 1,527 | 1,543 | 1,556 | 1,550 | 1,537 | 1,536 | 1,534 | 1,538 | 1,537 |
| 900 | 1,061 | 1,055 | 1,039 | 1,042 | 1,036 | 1,049 | 1,063 | 1,055 | 1,044 | 1,048 | 1,051 | 1,057 | 1,050 |
| 950 | 608 | 601 | 583 | 582 | 573 | 584 | 594 | 587 | 579 | 585 | 594 | 603 | 589 |
| 1,000 | 167 | 159 | 138 | 134 | 119 | 127 | 138 | 130 | 122 | 134 | 146 | 160 | 140 |
| SLP | 1,020 | 1,019 | 1,016 | 1,015 | 1,014 | 1,014 | 1,015 | 1,015 | 1,014 | 1,015 | 1,017 | 1,019 | 1,016 |

data for the three stations (fig. 1), are shown in tables 1–3. Seasonal changes at the individual stations, especially Burrwood and Brownsville, are quite large and the mean monthly data for the winter months can hardly be considered as representative of conditions in the whole of the triangle shown in figure 1. In the summer months, thermal conditions at the three stations are very similar and month-to-month changes are small. The mean soundings are, therefore, much more representative of normal conditions which would be expected over much of the Gulf of Mexico during this season. The major portion of the subsequent discussion deals with summer conditions; however, some use is made of the data for the other months in comparing seasonal variations over the Gulf of Mexico with those indicated for the West Indies area in [1].

TABLE 3.—*Mean humidity (percent) at standard pressure surfaces for Gulf of Mexico area*

| Pressure (mb.) | January | February | March | April | May | June | July | August | September | October | November | December | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 30 | 33 | 32 | 33 | 34 | 35 | 42 | 41 | 40 | 33 | 31 | 32 | 35 |
| 450 | 28 | 31 | 30 | 32 | 32 | 36 | 43 | 42 | 41 | 32 | 29 | 30 | 34 |
| 500 | 26 | 30 | 30 | 32 | 34 | 38 | 46 | 43 | 43 | 33 | 29 | 30 | 35 |
| 550 | 26 | 30 | 30 | 32 | 35 | 40 | 49 | 47 | 46 | 34 | 30 | 29 | 36 |
| 600 | 27 | 32 | 31 | 33 | 37 | 42 | 51 | 49 | 50 | 38 | 32 | 31 | 38 |
| 650 | 30 | 33 | 31 | 34 | 38 | 43 | 53 | 51 | 52 | 40 | 34 | 32 | 39 |
| 700 | 33 | 35 | 32 | 36 | 40 | 46 | 54 | 53 | 55 | 43 | 37 | 36 | 42 |
| 750 | 38 | 38 | 37 | 41 | 45 | 49 | 56 | 56 | 59 | 47 | 42 | 41 | 46 |
| 800 | 48 | 47 | 44 | 47 | 52 | 56 | 59 | 60 | 63 | 55 | 49 | 49 | 52 |
| 850 | 58 | 57 | 53 | 54 | 58 | 61 | 64 | 63 | 68 | 62 | 57 | 57 | 59 |
| 900 | 67 | 66 | 63 | 62 | 64 | 67 | 68 | 68 | 71 | 68 | 66 | 66 | 66 |
| 950 | 74 | 73 | 71 | 73 | 73 | 75 | 76 | 76 | 76 | 73 | 72 | 74 | 74 |
| 1,000 | 78 | 77 | 80 | 79 | 81 | 81 | 81 | 80 | 81 | 77 | 75 | 77 | 79 |
| Sfc | 84 | 82 | 83 | 82 | 84 | 84 | 83 | 83 | 84 | 83 | 82 | 83 | 83 |

TABLE 4.—*Mean Gulf of Mexico "hurricane season" sounding data for isobaric surfaces. Mean values of height (H), temperature (T), density (ρ), potential temperature (θ), equivalent potential temperature (θ_E), relative humidity (f), and specific humidity (q) are tabulated. Deviations (Δ) of mean Gulf of Mexico sounding data from mean West Indies sounding data are given for all of the above quantities*

| $P$ (mb.) | $H$ (ft.) | $H$ (m.) | $\Delta H$ (m.) | $T$ (° C.) | $\Delta T$ (° C.) | $\rho$ (kg./m.³) | $\Delta\rho$ (kg./m.³) | $\theta$ (° A.) | $\Delta\theta$ (° A.) | $\theta_E$ (° A.) | $\Delta\theta_E$ (° A.) | $f$ (%) | $\Delta f$ (%) | $q$ (g./kg.) | $\Delta q$ (g./kg.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 79,005 | 24,087 | 116 | −52.2 | 1.8 | 0.047 | −0.001 | 604 | 7 | | | | | | |
| 40 | 72,965 | 22,246 | 107 | −56.1 | 1.2 | .064 | −.001 | 531 | 7 | | | | | | |
| 50 | 68,355 | 20,840 | 97 | −59.0 | 1.6 | .080 | −.002 | 507 | 7 | | | | | | |
| 60 | 64,625 | 19,703 | 83 | −62.1 | 1.8 | .099 | −.001 | 474 | 6 | | | | | | |
| 80 | 58,875 | 17,950 | 63 | −67.6 | 2.2 | .136 | −.001 | 425 | 7 | | | | | | |
| 100 | 54,515 | 16,621 | 53 | −71.4 | 2.1 | .173 | −.001 | 391 | 5 | | | | | | |
| 125 | 50,200 | 15,305 | 45 | −70.9 | 1.3 | .215 | −.002 | 368 | 4 | | | | | | |
| 150 | 46,610 | 14,211 | 34 | −66.5 | 1.1 | .253 | −.001 | 356 | 2 | | | | | | |
| 175 | 43,505 | 13,264 | 26 | −60.7 | .8 | .287 | −.001 | 351 | 3 | | | | | | |
| 200 | 40,745 | 12,423 | 27 | −54.4 | .8 | .319 | −.001 | 347 | 2 | | | | | | |
| 250 | 35,930 | 10,955 | 20 | −42.7 | .6 | .378 | −.001 | 344 | 2 | | | | | | |
| 300 | 31,805 | 9,697 | 15 | −32.8 | .4 | .435 | +.001 | 340 | 2 | | | | | | |
| 350 | 28,185 | 8,593 | 12 | −24.4 | .4 | .488 | −.002 | 336 | 1 | | | | | | |
| 400 | 24,945 | 7,604 | 10 | −17.4 | .3 | .545 | 0 | 333 | 1 | 336 | ------ | 41 | ------ | 1.0 | ------ |
| 450 | 22,055 | 6,723 | 20 | −11.5 | .4 | .599 | 0 | 329 | 1 | 334 | 1 | 42 | 0 | 1.5 | 0.1 |
| 500 | 19,345 | 5,898 | 10 | −6.5 | .4 | .652 | −.001 | 325 | 1 | 332 | 0 | 44 | −1 | 2.1 | 0 |
| 550 | 16,890 | 5,149 | 11 | −2.1 | .4 | .706 | −.001 | 322 | 1 | 331 | −1 | 47 | 0 | 2.8 | .1 |
| 600 | 14,595 | 4,449 | 7 | 1.9 | .5 | .758 | −.002 | 318 | 0 | 330 | 1 | 50 | 0 | 3.7 | .1 |
| 650 | 12,470 | 3,802 | 10 | 5.6 | .5 | .809 | −.002 | 315 | 0 | 329 | 0 | 52 | −2 | 4.6 | 0 |
| 700 | 10,455 | 3,187 | 5 | 9.2 | .6 | .861 | −.001 | 313 | 1 | 330 | 0 | 54 | −3 | 5.7 | −.1 |
| 750 | 8,575 | 2,615 | 6 | 12.4 | .6 | .911 | −.002 | 310 | 1 | 331 | 0 | 57 | −4 | 7.0 | −.1 |
| 800 | 6,775 | 2,066 | 3 | 15.5 | .9 | .964 | 0 | 308 | 1 | 333 | 0 | 61 | −7 | 8.5 | .1 |
| 850 | 5,075 | 1,548 | 1 | 18.3 | 1.0 | 1.010 | −.003 | 305 | 1 | 336 | −1 | 65 | −9 | 10.3 | −.7 |
| 900 | 3,455 | 1,054 | 0 | 21.3 | 1.1 | 1.057 | −.005 | 303 | 1 | 340 | 0 | 69 | −10 | 12.6 | −.8 |
| 950 | 1,925 | 587 | 4 | 23.8 | .8 | 1.104 | −.004 | 301 | 1 | 345 | 1 | 76 | −5 | 15.2 | −.1 |
| 1,000 | 425 | 130 | −2 | 26.2 | .2 | 1.151 | −.001 | 299 | 0 | 349 | 0 | 81 | 0 | 17.7 | .1 |
| 1,015 | 0 | 0 | ------ | 26.4 | .1 | 1.161 | −.001 | 298 | 0 | 349 | 0 | 83 | −1 | 18.3 | .1 |

The data for the months July–September have been combined into a mean "hurricane season" sounding (table 4). The data are presented in the same form as the mean "hurricane season" sounding for the West Indies area [1] and deviations from the West Indies sounding are shown for all quantities. The "hurricane season" sounding for the West Indies area used data for the months July–October, but October was omitted in preparing the comparable sounding for the Gulf of Mexico area since the intrusion of westerlies at Brownsville and Burrwood is quite evident in the mean temperature data for October. This seasonal change in the circulation patterns is undoubtedly associated with the observed decrease in the frequency of tropical cyclogenesis between September and October [4], a tendency which is more marked in the Gulf of Mexico area than in the West Indies area.

There is little doubt that the "hurricane season" sounding offers a good approximation to normal summer conditions over the northern Gulf of Mexico. The deviations of the station means from the values given in table 4 were nearly all less than 1° C. at lower and middle tropospheric levels and less than 2° C. at all levels. Relative humidity values show more consistent deviations, with Brownsville running 4–5 percent less than the mean at some levels and Havana showing values greater than the means by a similar amount. The stations used in preparing the mean Gulf of Mexico soundings are not distributed so that the data can be considered truly representative of the portions of the Gulf of Mexico where tropical cyclogenesis is most frequent [4]. Data from the Mexican stations at Merida and Veracruz, combined with Burrwood and Brownsville, would probably have led to more representative soundings for the primary hurricane-formation area of the Gulf of Mexico. However, data for Merida and Veracruz—probably because of the shorter length of the records at these stations—were not included in the tabulations of mean aerological data [2].

The deviations shown in table 4 reveal that differences in the two "hurricane season" soundings are small throughout most of the troposphere. At levels up to 500 mb., the temperature and moisture differences are small enough so that the stability is almost identical over the two areas as revealed by the very small and unorganized differences between the equivalent potential temperature values for the two soundings.[3] However, the observed differences indicate that conditions over the Gulf are consistently warmer and drier than in the West Indies area. Deviations of this type in the troposphere are consistent with the fact that easterly flow increases with height over this area in association with the upper tropospheric anticyclone located over the southern United States during the summer months [5]. Stratospheric easterlies exist over the whole subtropical area in summer with maximum speeds above the 30-mb. level. The largest temperature differences shown in table 4 appear in the lower stratosphere where the mean easterlies increase most rapidly with height.

The fact that October data are included in the "hurricane season" sounding for the West Indies but not in the similar sounding for the Gulf area has a negligible effect on the features discussed above. This is evident from the fact that the temperature anomalies for the individual months, shown for selected levels in table 5, are very similar to those shown in table 4. The September deviations are smaller than those of the other months, and the vertical distribution is such that the stability over the Gulf, in comparison with the West Indies conditions, is slightly

[3] The deviations of equivalent potential temperatures given in table 4 are based on corrected values of the equivalent potential temperatures for the West Indies sounding which appear in a Corrigendum in the *Journal of Meteorology,* vol. 15, No. 6, December 1958, p. 512.

TABLE 5.—*Deviation of mean Gulf of Mexico temperature data (° C.) from mean West Indies temperature data at selected pressure surfaces for individual months*

| Pressure (mb.) | July | August | September |
|---|---|---|---|
| 50 | +1.2 | +1.2 | +1.5 |
| 100 | +1.1 | +1.8 | +.8 |
| 150 | +1.0 | +1.0 | +1.1 |
| 200 | +.8 | +.8 | +1.0 |
| 250 | +.8 | +.6 | +.6 |
| 300 | +.7 | +.5 | 0 |
| 400 | +.5 | +.3 | +.1 |
| 500 | +.6 | +.4 | +.4 |
| 600 | +.7 | +.6 | +.3 |
| 700 | +.7 | +.6 | +.2 |
| 800 | +1.1 | +.9 | +.2 |
| 900 | +1.5 | +1.2 | +.2 |
| 1,000 | +.1 | +.2 | −.4 |

greater during this month. However, considered over deep layers, differences are less than 1° C.

The fact that differences between the two mean "hurricane season" soundings are small and of such a form as to be consistent with the large-scale climatological features of the area suggests that the mean "hurricane season" sounding presented in [1], although based on data from only three stations, is probably a close approximation to mean conditions over an extensive area in the West Indies-Gulf of Mexico region. Comparison of the mean soundings for individual summer months for the two areas would reveal differences only slightly greater than shown for the "hurricane season" soundings in table 4. This fact, together with the information that synoptic variations are usually small in these areas in the summer months, suggests that these mean soundings may prove much more useful than similar soundings for other areas where the seasonal and geographical gradients, as well as synoptic variability, are much greater. Disturbances—in the form of tropical cyclones which affect most, or all, of the troposphere, and upper-level cyclones which affect the middle and upper troposphere—do occur in the Gulf of Mexico area during the summer months [5]. In the vicinity of these disturbances marked departures from mean conditions can be expected.

## 4. CLIMATOLOGICAL FEATURES

The mean West Indies data [1] showed that throughout most of the troposphere the warmest mean monthly temperatures are found in September and the coldest values in February. An almost complete reversal was noted in the 200- to 150-mb. layer with the maximum values in February and the minimum values in June–July. In the stratosphere, temperatures were warmest in June–July and coldest in January–February. The temperature data for the Gulf of Mexico area (table 1) show similar variations, except that at levels up to 600 mb. maximum values are observed in August (rather than September) and the reversal in the upper troposphere is first evident at 175 mb. rather than at the 200-mb. level. Also, the transition back to the "normal" seasonal pattern in the stratosphere occurs at a higher level, perhaps reflecting greater mean tropopause heights, with the 100-mb. level lying in the zone of small and somewhat irregular seasonal changes (table 1). The differences in the lower troposphere are consistent with the fact that Burrwood and Brownsville are affected by continental influences to a larger degree than the stations used in preparing the mean West Indies soundings. Cold-air outbreaks which are common at these stations during the winter months make the major contribution to the greater range of the mean monthly temperature at lower levels in comparison with those observed in the West Indies data (fig. 2). The magnitude of the range over the Gulf area is greater at all levels in the troposphere; however, the major features of the curves for the two areas are remarkably similar. Minimum values of the range are found in the vicinity of 700–600 mb. and 200 mb., and maximum values near the surface and 350 mb. In the stratosphere, the curves continue to be very similar, with the largest range shown in the West Indies data. The major features shown by this curve have been brought out in other studies [3].

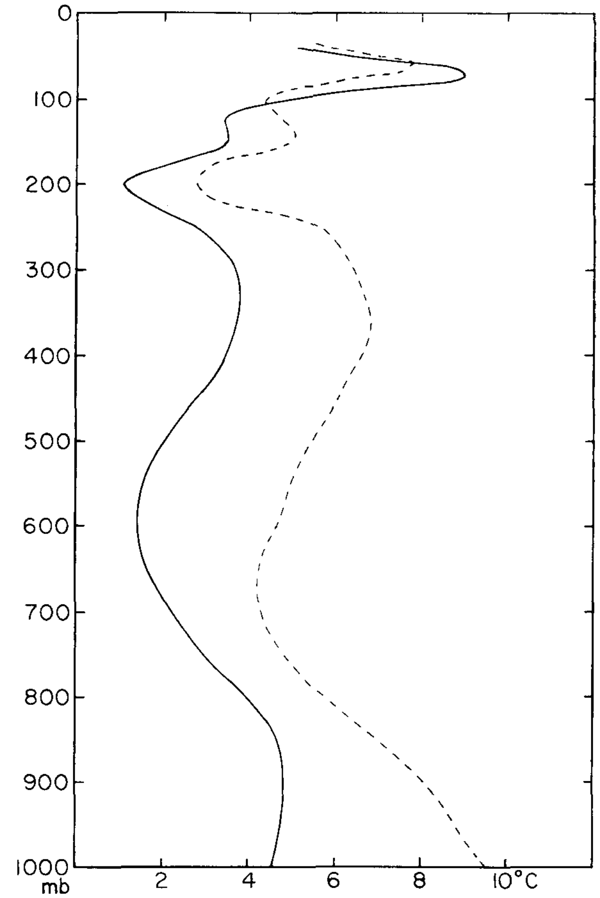


FIGURE 2.—The annual range of the mean monthly temperature for the Gulf of Mexico area (dashed) and the West Indies area (solid).

The mean West Indies data showed a marked departure from the normal seasonal trend in early summer with cooling being shown from June to July at tropospheric levels above 700 mb. A similar break in the normal seasonal temperature change is evident in the Gulf data (table 1) but it is weaker and cooling is found only in the 700- and 500-mb. layer.

The mean relative humidity data for the Gulf area were

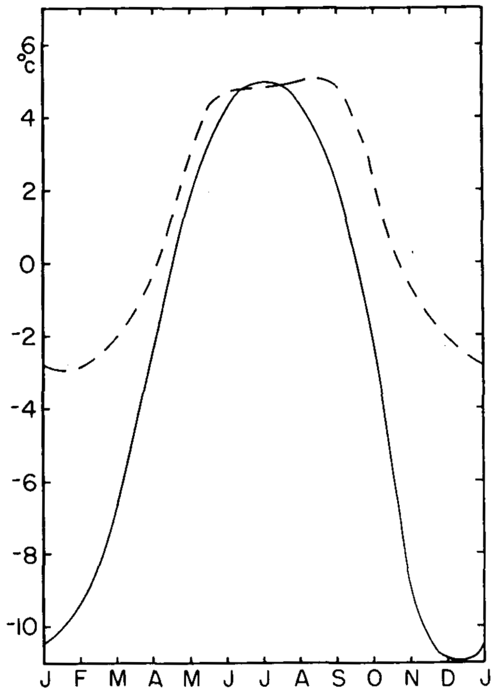


FIGURE 3.—Seasonal course of the Palmén instability index for the Gulf of Mexico area (solid) and West Indies area (dashed).

consistently lower than the mean West Indies values. The maximum deviations were generally in the 900- and 850-mb. layer where, during all months except September, the Gulf values were at least 10 percent less than the West Indies values. During July and August, this relatively dry layer still persisted, but at higher levels the Gulf values were as great as or greater than those for the West Indies area. The low humidities in the 900–800-mb. layer in the summer months, together with the fact that temperature deviations reach a maximum in this vicinity (tables 4, 5), suggest that subsidence is a more prominent feature in this layer over the Gulf of Mexico than over the West Indies area.

It has been pointed out that there are systematic differences between the mean West Indies and Gulf soundings throughout the year, although differences are rather small during the summer months. These two sets of soundings have been studied in relation to the frequency of hurricane formation by computing the Palmén instability index for each area. This index, which Palmén [6] used in his study of climatological aspects of hurricane formation, is defined as the difference between the mean 300-mb. temperature and the temperature of a parcel lifted pseudoadiabatically to this level from the earth's surface. Positive values of the index were considered as a necessary, but not sufficient, condition for hurricane formation.

The Palmén index has been computed for each month of the year using the mean surface and 300-mb. data for the West Indies and Gulf of Mexico areas (fig. 3). The September values in both areas are somewhat lower than those shown by Palmén which attained values of over 9° C. in the Gulf of Mexico area. Similarly, Palmén showed slightly positive values in the West Indies area in February, while figure 3 shows negative values throughout the winter months. This difference can be accounted for by the fact that Palmén used sea surface temperatures and assumed the surface relative humidity to be 85 percent throughout the whole area considered. He used mean 300-mb. data for September and February from Swan Island. Actually the air temperature is generally slightly lower than the water temperature, and this difference is accentuated in the present case since the mean West Indies and Gulf soundings are based on data taken only at 0300 GMT. In addition, relative humidity values are less than 85 percent in some months, especially in winter.

The curves of the Palmén index (fig. 3) show a marked seasonal trend which is of the same type in the two areas and which agrees in a qualitative sense with the observed frequency of hurricane formation. Hurricanes are rare during the months which show negative values of the index and a maximum frequency is reached during the months which show positive values. However, the index rises sharply during the spring months and reaches high values in June and July when hurricanes are rare. The index for the Gulf area has already started to fall quite rapidly by September when the maximum of hurricane formation is reached. It is of interest that there are relatively large differences in the value of the index between the two areas in October and November when hurricane formation is still frequent in the West Indies-Caribbean area and much less frequent in the Gulf of Mexico area [4].

Hurricanes form with some regularity in the Gulf of Mexico in October and in the West Indies region in November, although the mean instability index is slightly negative in these areas during these months. However, the hurricane formation periods may well coincide with abnormal periods when the index is positive. Of course, not all features of the seasonal distribution of hurricanes should be expected to fit in with the mean seasonal curves of the simple instability index. The importance of other factors is clearly suggested by the fact that higher values of the index are shown in June–July than in September, although there is a large increase in the frequency of hurricanes between June and September in both areas.

## REFERENCES

1. C. L. Jordan, "Mean Soundings for the West Indies Area," *Journal of Meteorology*, vol. 15, No. 1, Feb. 1958, pp. 91–97.
2. B. Ratner, "Upper Air Climatology of the United States. Part I—Averages for Isobaric Surfaces, Height, Temperature, Humidity, and Density," U.S. Weather Bureau *Technical Paper No. 32*, Washington, D.C., 1957.
3. H. Riehl, *Tropical Meteorology*. McGraw-Hill Book Co., Inc., New York, 1954, 392 pp.
4. J. A. Colón, "A Study of Hurricane Tracks for Forecasting Purposes," *Monthly Weather Review*, vol. 81, No. 3, Mar. 1953, pp. 53–66.
5. G. Dean, The 250 mb. Seasonal Wind Circulation Over the Caribbean During 1956–57. (Unpublished.)
6. E. Palmén, "On the Formation and Structure of Tropical Hurricanes," *Geophysica*, vol. 3, 1948, pp. 26–38.